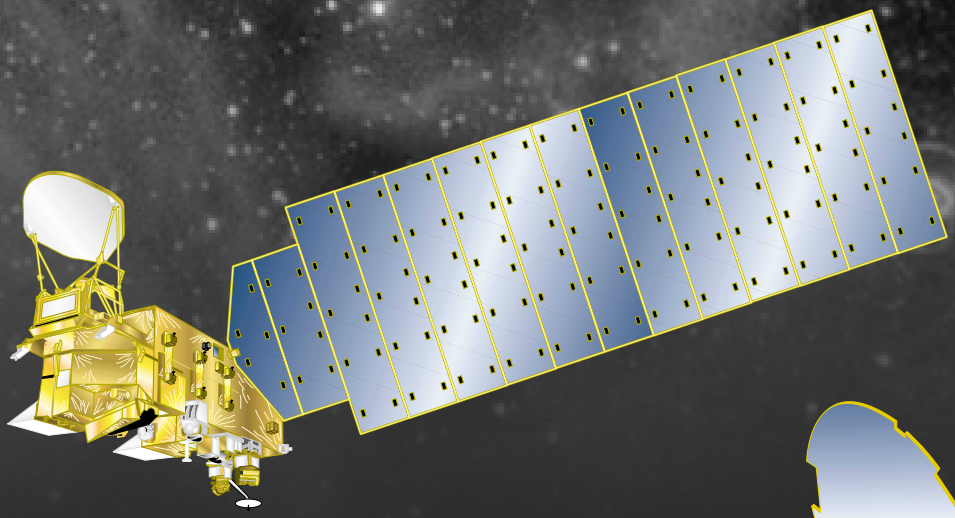
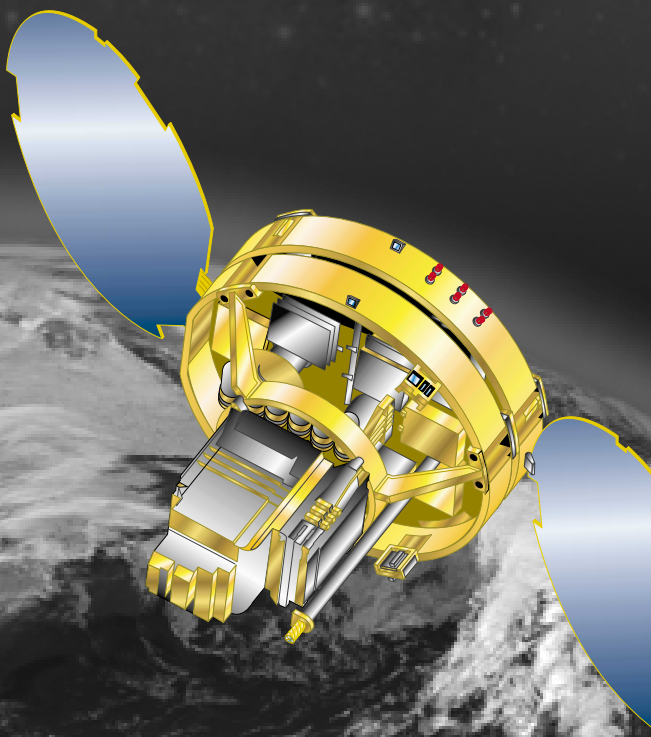
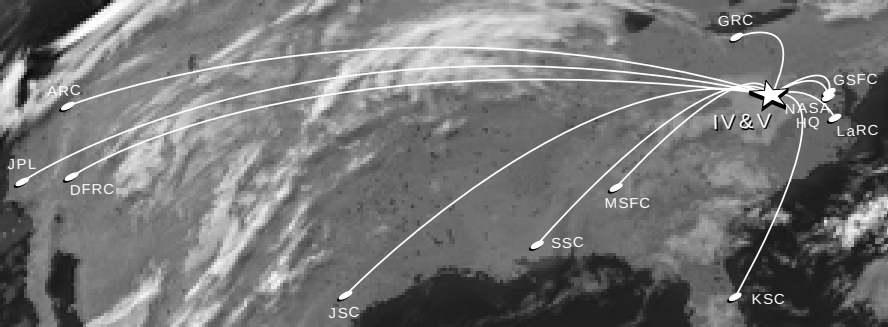
National Aeronautics and Space Administration

INDEPENDENT VERIFICATION & VALIDATION FACILITY

Program Plan







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PROGRAM PLAN

FOR THE

INDEPENDENT VERIFICATION AND VALIDATION FACILITY

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PREFACE

NASA software management policies that govern the application of Independent Verification and Validation (IV&V) of mission software are being formalized as this Program Plan is being published. This plan conforms with interim policies and criteria.

1 INTRODUCTION

The success of NASA missions demands that there be a coordinated effort for the development, verification, and validation of critical flight and ground software. NASA's Independent Verification and Validation (IV&V) Facility was established in October 1991 by the FY 1992 VA-HUD-Independent Agencies Appropriations Act (P.L.102-139). This action, initiated by Senator Byrd, addressed recommendations made by the National Research Council and the Report of the Presidential Commission on the Space Shuttle Challenger Accident. The Facility was tasked to provide the highest achievable levels of safety and cost-effectiveness for mission-critical software. The mission of the Facility, located in Fairmont, West Virginia, is to become the NASA center of expertise for the application of independent verification and validation processes and technology to improve reliability and reduce risk of software systems.

IV&V is a systems engineering and management discipline that identifies software risk to improve safety and quality. IV&V is performed throughout the development life cycle to evaluate the quality of the software processes and products and to ensure software operates safely and within its designed parameters. Verification consists of proof of compliance with specifications and may be determined by test, analysis, demonstration, and inspection. Validation consists of proof that the system will accomplish its intended purpose. IV&V is defined by two parameters: technical independence and managerial independence. Technical independence engages personnel who are not involved in the implementation to assess development processes and products independent of the developer. They formulate their own understanding of potential problems and how the proposed system is solving them. Managerial independence requires responsibility for the IV&V effort to be vested in an organization separate from the organization responsible for performing the implementation of the system (e.g., development contractor). The IV&V organization independently selects the segments of the software and system to analyze and test (in consultation with NASA Project Management), chooses the IV&V techniques, defines the schedule of IV&V activities, and selects the specific technical issues and problems to act upon. IV&V findings and recommendations are to be shared with the developer and project organization to affect improvements.

To further improve the safety, productivity, and success of NASA's missions, NASA was charged by House Conference Report 106-379 to reexamine the role of its Facility in Fairmont, West Virginia. "The conferees expect substantial integration of the Facility into the NASA system, and, in particular, the activities of the Goddard Space Flight Center (GSFC). This Center should take specific note of this opportunity due to its close proximity to the Facility. To these ends, the conferees direct the Administrator to report, in conjunction with GSFC and no later than June 1, 2000, on what new activities the various NASA Centers are initiating with the Facility." In this regard, NASA Headquarters asked GSFC to develop a Business Plan to ensure the long-term vitality of the Facility. The stated goal was to ensure the effective utilization of NASA's IV&V capabilities to reduce risk in NASA missions, to strengthen the IV&V Facility's capabilities to support NASA's software development projects, and to assure that the Facility develops a business base for sustainable operation.

The Business Plan for the Facility was completed by GSFC on May 31, 2000, and signed by the responsible NASA Headquarters officials on June 2. This Business Plan summarized the current capabilities of the Facility for performing IV&V and for supporting technology development in the context of the current projects being supported. NASA's policy for applying IV&V to mission software was strengthened to assure that software assurance actions are applied consistently based on risk, and this policy was documented in the Plan. The profile of future missions was identified, and steps were outlined for the transfer of the Facility from Ames Research Center to GSFC to provide a stronger coupling to flight project management. Potential opportunities for additional IV&V-related work were identified for further consideration to leverage the Facility's capabilities and strengthen its role in NASA programs.

The transition steps defined in the Business Plan were completed on July 2, 2000, and the Facility became an organizational element of GSFC. This Program Plan was then developed to establish the IV&V Facility's roles, objectives, and management approach for supporting NASA missions and for managing the development of supporting technology. This Plan also continues the investigation of other opportunities for leveraging the Facility's capabilities.

The purpose of this Program Plan is to:

- Establish the mission and management objectives for the IV&V Facility;
- Define the roles of the Facility in performing IV&V for software projects, and in managing and performing research; and
- Define processes for resources planning and funding.

The emphasis of this Plan is to document the objectives and processes. The actual projects supported by the IV&V Facility and the resources required to perform the work will be determined based on NASA mission plans and mission software risks.

Identification of potential IV&V projects, budgets and staffing profiles will require updates on an annual or more frequent basis. Projects, budgets, and staffing projections will be documented annually in a separate Operating Plan. More detailed information by mission will be provided to Enterprises and Centers in separate supporting data packages.

2 IV&V PROGRAM OBJECTIVES

The Facility represents a unique capability in NASA and potentially in the nation. The Facility and its IV&V program have the charter to be NASA's center of expertise for software reliability assurance. The civil service and contractor personnel at the Facility and at customer development sites have demonstrated the benefits of their work through a high degree of customer satisfaction. NASA's IV&V policy mandates that all NASA missions apply IV&V where needed based on risk assessment. The Facility now faces the challenge of serving as the Agency's center of expertise for IV&V.

In order to maintain a high level of competence in applying IV&V to software projects, the Facility will need to manage a strong program in IV&V technology, and to build relationships with related software engineering technology efforts. This will be needed to both maintain the ability to perform IV&V for software projects with increasing complexity within customer project budget constraints, and to develop appropriate IV&V methods for application to emerging software technologies.

The Facility will need to continually assess its processes and develop improvements in processes and tools to effectively support the customer base. Opportunities need to be explored to maximize utilization of Facility resources.

Once the Facility has achieved the full range of skills needed to provide IV&V for NASA missions, new opportunities can be explored to leverage the IV&V capability outside of NASA, for example by seeking joint projects with other agencies. This would increase stability of the workload and further increase the available workforce, benefiting the Facility, NASA, and new customers of the Facility.

Sections 3 through 6 of this Program Plan address the top priority objectives by defining the process needed to perform IV&V for NASA missions:

- Defining the planning and management processes for developing and providing IV&V support to NASA missions; and
- Defining the processes used to develop an IV&V Mission Model and to estimate the required budget to support that model.

Section 7 provides a management plan for technology development to assure that the Facility remains a center of expertise in IV&V methodologies, tools, and applications.

Section 8 discusses progress in investigating opportunities for leveraging the Facility's capabilities to support related NASA software engineering needs.

Section 9 defines the process for annual review and update of the work plans and budget for the IV&V Facility.

3 IV&V MANAGEMENT PLAN

3.1 Risk Based Management

The first version of the IV&V policy was published in the Facility Business Plan in June 2000. A strengthened interpretation of NASA's IV&V policy was issued by the NASA Chief Engineer in a letter to all NASA projects clearly specifying the process for determining when a program must apply Independent Assessment (IA) or IV&V. The final policy will be baselined as NASA Policy Directive (NPD) and NASA Procedures and Guidelines (NPG) documents.

One strength of the policy is the specification that the Facility is responsible for the management of the Agency's software IV&V activities. The Facility's role is to provide a value-added service to the Agency's software development efforts. All findings will be reported directly to developers to enable corrective action to be taken. Overall results will be reported to Project Managers and Center Project Management organizations. A central repository of knowledge, tools, metrics and lessons learned will thus be maintained to support improved software development and IV&V practices for future projects throughout NASA.

NASA projects covered by the IV&V policy will produce, document, and implement a plan that addresses the performance of V&V, and if appropriate, IV&V, over the life cycle of the software, from requirements through delivery and maintenance. The level of IV&V of software that is performed is based on the cost, size, complexity, life span, risk, and consequences of failure.

The process for that determination is as follows:

a. The project manager will evaluate their project against the criteria to determine if IV&V is indicated.

b. For projects where the criteria indicates software IA or IV&V is warranted, the project manager will discuss the results with a representative of the Facility. Application of the IV&V criteria simply determines if a project is a candidate for IV&V – not the level of IV&V nor the resources associated with the IV&V. The Facility personnel will work jointly with the project office to provide recommendations tailored to that project on the extent to which IV&V should be performed for mission software elements.

c. With this input from the Facility, the project manager will document in the project plan what IV&V is intended to be performed. Since IV&V complements and enhances risk mitigation, projects are encouraged to achieve the most effective balance of risk mitigation strategies.

d. The project's Governing Program Management Council (GPMC) is responsible for reviewing the IV&V recommendations and approving the project's IV&V approach as part of its general oversight responsibility.

3.2 Roles and Responsibilties

The Facility provides IV&V support and manages and performs IV&V research to improve the effectiveness of its tools and processes, and to maintain pace with advances in software engineering paradigms and methodologies in future NASA software systems. The degree of IV&V support required by projects is determined based on NASA IV&V policy that prescribes criteria for requiring IV&V, a process for developing agreements on IV&V plans between the Facility and customer projects, and a review process to assure that sufficient IV&V effort is being applied.

Figure 3.3-1 shows the responsibilities of NASA Headquarters, Center organizations, and the Facility in executing NASA's IV&V Program.

The following sections describe the Facility approach for providing support to customer projects.

3.2.1 Facility Success Criteria

In order to assess the Facility's success in performing IV&V, a metrics program is needed to identify and track the success factors used to measure the Facility's performance. Currently there is no formal metrics program for measuring the Facility's success overall, though customer satisfaction has been identified as a fundamental objective of the Facility, and metrics are collected on this.

The Facility is developing an internal metrics program to assess its overall success in achieving mission goals. This program is being patterned after the NASA software development metrics program that was initiated in July 2000 by the NASA SWG and the Facility. Under this program, the Facility is responsible for gathering software development metrics for projects covered by NPG 7120.5. This program is using a selected set of projects to determine if the right set of metrics is being collected, test the effectiveness of the collection system, validate analyses that should be performed, and evaluate reports that are generated.

This internal program will evaluate how well the Facility is achieving its mission objectives. Data from current and past IV&V projects and existing knowledge of IV&V processes and products is being used to identify an initial set of metrics and interpretation guidelines. A data collection method similar to the one described above will be developed. The pilot project will run for approximately six months. During that time, trending will be done. At the conclusion of the pilot, the final set of metrics will be identified. These metrics will then be collected on all projects implementing IV&V.

While the final list of metrics to be used will not be formalized until the end of the pilot period, the initial pilot set will include data that addresses the effectiveness of the Facility in performing IV&V in support of missions, including:

- customer and stakeholder[1] satisfaction and
- operational performance of Agency software that has undergone formal IV&V.

It is also expected that the metrics program will track a number of data points on an annual basis to measure the efficiency of the Facility in providing support, including the relationship and trends among:

- the number of flight projects supported,
- the number/location of Full-Time Equivalents (FTEs) employed by and at the Facility, and
- the overall operating budget of the Facility.

It should be noted that customer satisfaction is currently being measured by feedback received in the form of a customer survey instituted as part of the Facility's International Standards Organization (ISO) Quality Management System. This system, instituted in October 1998 when the Facility was certified as ISO 9001 compliant, requires that a customer satisfaction questionnaire be completed annually or at the completion of the project. Given the relatively short time since receiving ISO certification, little trending data is available. As more data becomes available, it will be possible to monitor specific performance trends in key areas such as quality of work performed, cost, schedule and responsiveness. These trends will be used to highlight areas for improvement with respect to customer satisfaction. It is anticipated that the new internal metrics program under development will incorporate and expand on this metric and collection system. It will also establish a process for monitoring trends and initiating actions when appropriate.

3.2.2 Project Support Approach

A key objective of the Facility is to provide value-added support to each customer. To this end, a consistent approach has been established and documented for providing project support. The Facility's ISO document 53.IT.0009-4 Rev H (Project Management) provides a

[1] Customer and stakeholder are defined as the person sponsoring the work, such as the project manager.

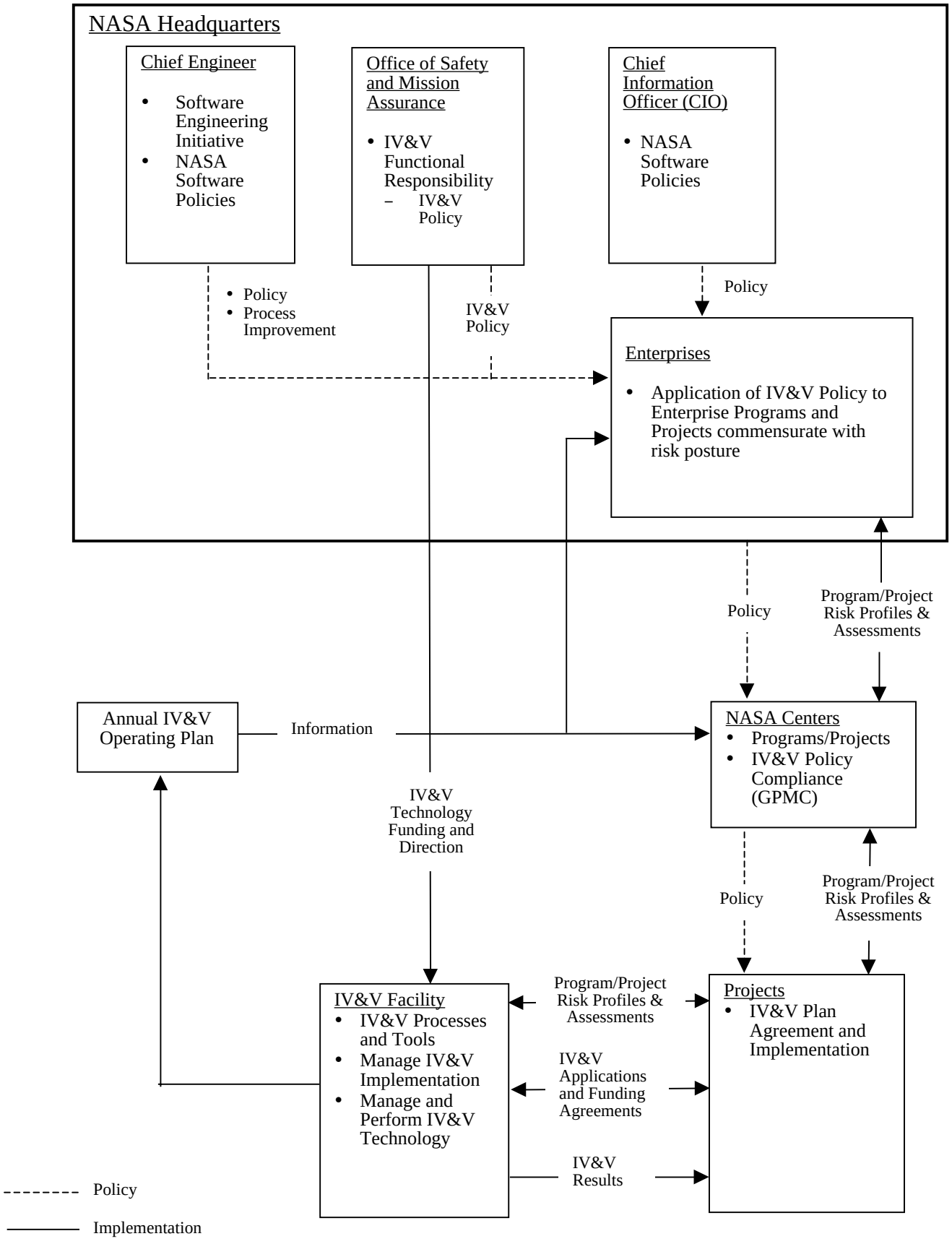

Figure 3.3-1 NASA IV&V Management.

detailed description of the method used to manage the IV&V support provided to customers. A brief summary follows.

An IV&V Project Manager (IV&V PM) will be assigned to each customer. The IV&V PM will initiate contact with a potential customer based on the current Mission Model (described in Section 5) or in response to an inquiry from the project. Preferably, discussions will be initiated with a project during the requirements definition phase of the life cycle. The IV&V PM will discuss the level of support required/desired by the customer and negotiate a formal agreement with the project point of contact. The agreement will document the work to be performed and the resources required. The form of the agreement will generally be a Memorandum of Agreement (MOA), though it could be a Program Activity Commitment Term (PACT) or contract.

The IV&V PM will hold discussions with the customer to establish the services desired, any special hardware or software resources required, and the timeframe in which the work is to be performed. Once the initial scope of the work to be performed has been agreed to, the IV&V PM will identify team members to perform the work. The process for negotiating IV&V support with new missions is shown in Figure 3.3.-2.

Initial discussions will be followed by in-depth discussions, during which specific tasks will be identified and costs will be determined. Once the Facility and customer have reached general agreement on the support to be provided, the formal agreement will be finalized, reviewed, and signed by all parties. The formal agreement will define the level of support to be provided and will identify specific tasks to be accomplished. These tasks may include one or more of the following phase independent analyses:

- Traceability analysis
- Issues tracking
- Metrics assessment
- Loading analysis
- Change impact analysis
- Special studies

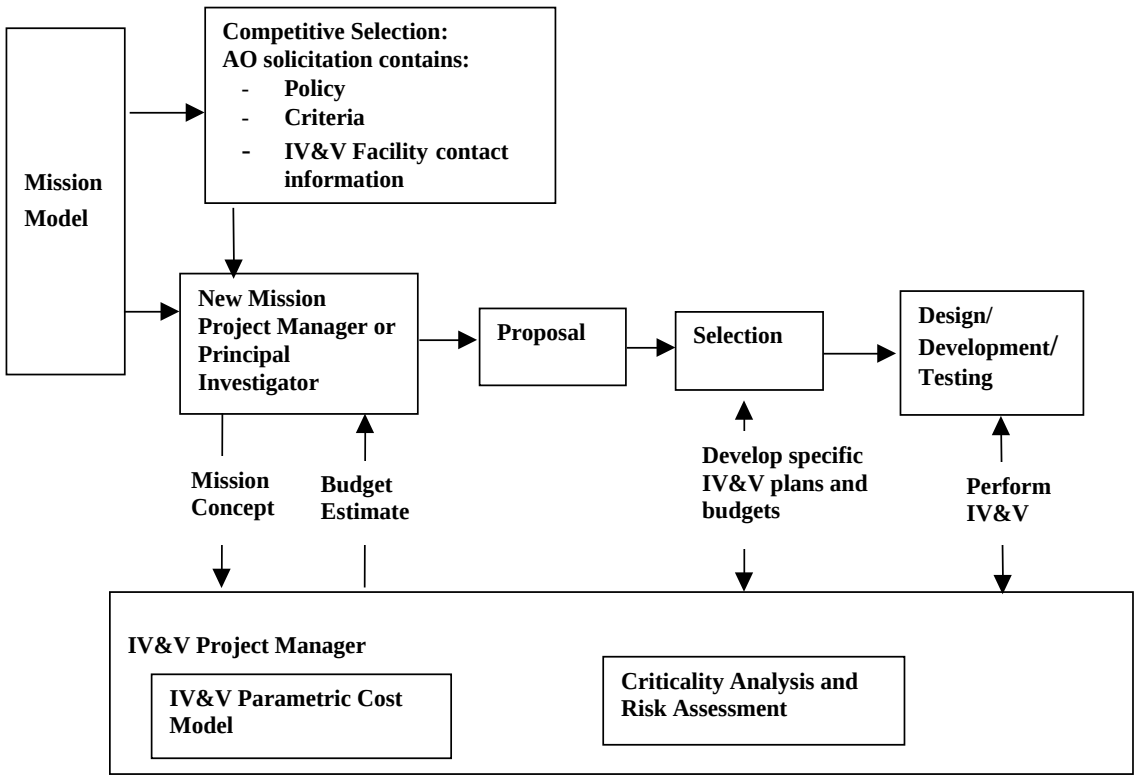

Figure 3.3-2 Planning IV&V Support for New Missions.

They could also include one or more of the following phase dependent analyses:

- Documentation reviews
- Process analysis
- Software requirements analysis
- Interface requirements analysis
- Software design analysis
- Code analysis
- Analysis of the Project's V&V test program
- Supportability analysis
- Technical reviews
- IV&V testing

At this point, the IV&V PM will create a Project Plan. The Plan will then be executed, with the PM providing management oversight and ensuring that all deliverables meet specified requirements and are delivered on schedule. The IV&V PM will interface with the customer PM on a regular basis, including telecons, status briefings, etc. as outlined in the Project Plan. Additionally, the IV&V team will interact with the developer team at the working level on a daily basis. They will be an integral part of the overall mission team, reviewing documents and tests, writing code, and providing immediate feedback to developers. The IV&V PM will work closely with the customer to handle any nonconformances and agreement modifications as described in the formal agreement, and will prepare a final closure report at the end of performance on the project. The report will include a summary of contributions to the project as well as recommendations/lessons learned for potential use by other projects.

4 BENCHMARKING THE NASA IV&V PROCESS

4.1 Benchmarking Approach

A benchmarking effort was performed to revalidate that the IV&V activities presently defined by the Facility procedures are in-line with industry, other Government agencies, and academia. This analysis was also undertaken to capture any IV&V best practices for incorporation into future Facility processes.

The benchmarking was performed by comparing processes and procedures as practiced at the Facility to IV&V processes as documented by other organizations:

1. "A Guide to Independent Verification and Validation of Computer Software," US Army Belvoir RDT&E Center, Fort Belvoir, Report Number 2516, June 1992.
2. "FAA Statement of Work for Independent Verification and Validation," July 1991.
3. "Acquisition Management Software Independent Verification and Validation," Department of the Air Force, AFSC/AFLC Pamphlet 800-5, May 20, 1988.
4. "Software Quality Engineering A Total Technical and Management Approach," Michael S. Deutsch and Ronald R. Willis, 1988.

4.2 Analysis Results

The overall result of the analysis is that the IV&V activities defined by the Facility are comprehensive when compared to other organizations (as shown in Table 4-1). During the benchmarking analysis there were several IV&V activities identified by other organizations that, on first inspection, were not clearly identifiable in the Facility's activities. However, further analysis revealed that each activity in another organization's process was found to be a sub-process of a higher level IV&V activity. These sub-processes are also identified in Table 4-1. There was no indication that other organizations were performing any IV&V activities not already defined by the Facility.

It should be noted that the Facility has defined three IV&V support activities not specifically addressed by other organizations:

- Issues Tracking
- Metrics Assessment
- Supportability Analysis

Table 4-1. Comparison of Facility Process to Other Organizations

	Independent Verification and Validation Activities	IV&V Facility	Government	Industry	Comment
1	Criticality Analysis/Risk Assessment (CARA)	**X**	X		
2	Traceability Analysis	**X**	X		
3	***Issues Tracking***	**X**			
4	***Metrics Assessment***	**X**			
5	Loading Analysis	**X**	X		
6	Change Impact Analysis	**X**	X		
7	Special Studies	**X**	X		
8	Document Review	**X**	X		
9	Process Analysis	**X**	X		Includes walkthroughs and test support
10	Software Requirements Analysis; Including Interface Reqts	**X**	X	X	
11	Software Design Analysis	**X**	X	X	Includes rederive key design algorithms
12	Code Analysis	**X**	X	X	
13	Analysis of V&V Test Program	**X**	X		Includes output validation
14	***Supportability Analysis***	**X**			
15	Technical Review Support	**X**	X		Includes audit support
16	IV&V Testing	**X**	X	X	Includes integration, test and simulation
17	Certification of Readiness	**X**	X		Includes end item analysis

The first activity is more a byproduct of normal business operations than a special IV&V activity and is considered a best practice. The second activity looks at metrics generated during a software life cycle, an important capability given the recent emphasis on the proper application and use of software metrics. The last added activity was developed for specific NASA customers and retained as an IV&V service that can be provided to any customer. All three of these activities evolved from early support to NASA projects and are now part of the standard list of IV&V activities.

The Facility has the ability to support Software System Safety. The NASA Software Safety Standard (NASA-STD-8719.13A) states that one of the objectives of the software safety process is to ensure that appropriate verification and validation requirements are established to ensure proper implementation of software safety requirements. This explicitly includes an assessment of the scope of IV&V to be planned and implemented. This entails the identification of IV&V activities (taken from the present list of activities) that best mitigate areas of software safety risk.

The Facility also performs Independent Assessments that support the overall software IV&V process. The IA has three components: a systems assessment (short-term), life cycle assessment (long-term), and criticality risk assessment. The overall focus of the IA is to review and analyze the software system processes and products applied throughout the life cycle to identify software risks that could jeopardize mission safety and success.

The end result of this analysis is that the Facility provides a comprehensive suite of IV&V activities, to be performed at the Facility or at development sites as appropriate. They have learned to incorporate additional activities as a result of lessons learned in supporting NASA projects. The Facility has also instituted an IA process for the assessment of software risk. A near-term improvement to the overall IV&V process at the Facility is a formalization of a process to regularly monitor ongoing trends in other organizations' IV&V approaches and best practices and incorporate appropriate changes into the Facility's IV&V practices.

Of the seventeen IV&V activities defined by the Facility, eight can be performed remotely from the development site:

- Traceability Analysis
- Loading Analysis
- Change Impact Analysis
- Software Requirements Analysis
- Software Design Analysis
- Support Analyses
- Document Review
- Issues Tracking

Three activities require some level of support at the development site:

- Test Program Analysis
- Metrics Assessment
- Criticality Analysis/Risk Assessment

The remaining six activities generally need to be performed at the development and integration site to provide direct interaction with test facilities and the development team:

- Special Studies
- Process Analysis
- Code Analysis
- Technical Review Support
- IV&V Testing
- Certification of Readiness

The Facility has taken action to acquire the necessary improvements to the Facility Information Technology (IT) infrastructure. The Facility is in the process of acquiring updates to the Local Area Network (LAN), additional computer hardware and software resources, and telephones that is sized to support planned growth of the current civil servant staff. The present email capability is sufficient to support project traffic increases. The Facility IT security capability is consistent with standard practices, and there are plans in place to ensure secure handling of projected increases in file transfer traffic. The Facility has a comprehensive security risk assessment underway, which to date shows that security efforts are effective.

The Facility is well positioned to provide remote support to projects. To improve an already strong capability, GSFC is negotiating with other NASA organizations for possible application of collaborative engineering support capabilities to the Facility's IV&V process. These capabilities would enable engineers located at several remote sites to view/work on shared information (e.g., requirements, design, and drawings), through interactive display, video, and audio. This state-of-the-art technology would also better enable Facility personnel to interact with projects and contractors to achieve mission success through application of remote IV&V activities.

5 PROJECTED IV&V MISSION MODEL

The Facility will maintain a baseline of current IV&V requirements and commitments, and will work with the Enterprises and Centers to periodically update a forecast of potential future missions and their software characteristics to support projections of IV&V workload, staffing, budgets, and other resource requirements. The first projection of future Facility work in the context of the strengthened NASA IV&V policy was developed during the writing of this Program Plan. This section describes the process used to develop this forecast.

5.1 Process for Developing Preliminary IV&V Mission Model

Making best use of NASA's software engineering talents and historical knowledge of IV&V efforts, a mission model was developed of those missions that are candidates for software IV&V or IA.

The NASA SWG, comprised of representatives from all NASA centers, developed interim criteria for determining whether IV&V or a software IA should be applied to a project's software development effort. These criteria were then included in direction from the NASA Chief Engineer to NASA projects. Project Managers were

required to assess their project's overall mission and software environment using these criteria to provide a preliminary determination of whether IV&V or IA may be required for any of their software elements. The results were entered by each project into a web-based application created for this purpose. These results were then evaluated, and, in a few cases where the responses appeared to be inconsistent with expectations, the projects were contacted to assure that the criteria were being correctly interpreted. Also, in some cases where IV&V was identified as potentially required by the application of the criteria but the project was close to launch, the performance of IV&V was not viewed as cost effective. These projects were targeted for initially receiving IA's, with IV&V being required if the IA revealed potentially unacceptable risks. The above effort resulted in a Preliminary IV&V Mission Model for FY01-FY05 in June 2000.

As future NASA missions are identified, the IV&V criteria will be applied and the IV&V Mission Model will be updated accordingly. Also, the NASA SWG has in place plans to revisit the criteria to refine them over time as experience is gained with their application.

5.2 Potential Mission List for IV&V

The Preliminary IV&V Mission Model resulting from the process described in Section 5.1 comprises the initial estimate of those projects that, due to apparent software criticality and risk, may benefit from the application of software IV&V or IA. The determination of whether IV&V or IA is actually performed on a project, the software elements to focus on, and the size of the effort required, will be based on a more detailed analysis by the Facility and the project of the probability of software failure and of the impact of software failure on the mission. This determination is then subject to the review by the project's GPMC.

Initial IV&V estimates are updated by working directly with NASA projects. Results of working with those projects nearing their launch dates were incorporated to produce an updated IV&V mission model in March 2001. This model documents the potential future work for the IV&V Facility and provides the basis for the resources planning process described in Section 6.

In order to maximize the benefits of IV&V to projects under development, the Facility will work with management at NASA centers to establish priorities.

5.3 Process for Updating Potential IV&V Mission Model

The Facility will work with projects, Centers, and Enterprises to regularly update the Potential IV&V Mission Model to ensure a commonly understood basis for planning future IV&V efforts and budgets. Information on potential future missions will be drawn from Enterprise plans, Center programs, Announcements of Opportunity (AO), and other sources. Mission characteristics and expected IV&V requirements will be identified by applying the IV&V criteria. Estimated budgets and staffing requirements will be developed as described in Section 6. The overall update process for IV&V planning is described in Section 9.

6 IV&V RESOURCES PLANNING

Using the IV&V Mission Model developed as described in Section 5, Facility personnel utilize historical knowledge of past IV&V efforts to estimate the resources necessary to support the projects identified as potentially needing IV&V or IA. These resources include estimated cost by project, projected contractor staffing at the Facility and at development sites, civil service staffing required to manage IV&V application and technology programs, and Facility space, computing, networks, and other resources.

6.1 Process for Developing IV&V Resource Estimates

The Facility has been performing IV&V on selected NASA projects since 1994. This experience base is used to apply historical knowledge to the IV&V Mission

Model described in Section 5 to determine an initial staffing estimate and cost profile for each project in the model. The process utilized is as follows:

- For those projects where agreements already exist for the performance of work by the Facility, cost and personnel requirements are taken from those agreements. Where appropriate, out-year projections are made.
- For projects having no current Facility involvement, an estimate is made of the level of personnel support required based on project attributes and on the IV&V Facility's past experience with similar projects. The following general approach is used:
  - Requirements for IAs vs IV&V are identified by applying the IV&V criteria. This determination can generally only be made for missions in the formulation or implementation phases. In applying this process for the first time in FY01, the number of projects requiring IA was increased due to the number of projects nearing their delivery dates. (IV&V will still be performed for these projects if the IA process indicates unacceptable risk.) Projects in future years will generally require IV&V, and the number of IAs is expected to decline. However, there will still be small (e.g., university-class) missions that may not require full IV&V, and NASA non-flight software development projects may benefit from the IA process. An estimate of 75% of the FY01 number of IAs was therefore assumed in each of the subsequent years to cover this potential. Required staffing to perform IAs is based on an average of 0.3 contractors and 0.12 civil servants per IA.
  - Projects classified as type *Space Vehicle (Not Human-Rated), Planetary/Deep Space Vehicle, Planetary Lander or Atmospheric Vehicle (Not Human-Rated)*, are estimated as requiring 5.5 IV&V personnel performing IV&V from three months before the Implementation phase to four months after delivery. Thirty percent of this loading was assumed to be required from the Projected Start date until three months before Implementation. Forty percent of the full loading was assumed from four months after delivery until six months after the mission is operational.
  - Projects classified as type *Space Platform (Not Human-Rated) or Flight/Space Instrument* used the same percentage loading as above, however are based on a peak loading of 3.5 vs 5.5 IV&V personnel. The difference is attributable to the more complex nature of the former on the average.
  - Large projects and human-rated flight missions require larger IV&V teams. Staffing for these projects is determined on a case-by-case basis.
  - Knowledge of any mission-unique characteristics is then applied to these estimates (e.g., the Mars 2003 mission has two landers, so the estimate for that mission was increased).
  - Estimates for future NASA projects (e.g., Discovery missions 09 through 12) are made based upon project type and schedule.
  - Civil servants are assigned responsibility as project managers for each of the customer project IV&V/IA efforts. Civil service staffing requirements for IV&V management are shown in Table 6.1-1.
  - Contractor and civil service staffing profiles are then prorated based upon the phasing of each project during each fiscal year.
- Finally, costs are assigned based upon the number of contractor FTEs indicated per fiscal year. Recognition was given in these computations that personnel costs are necessarily higher per person on smaller projects due to a greater percentage of work involving analysis vs performing routine procedures.

Table 6.1-1 Civil Service Staffing Per Project Per Year

Activity	Size of IV&V Activity	Peak Number of Contractors per Activity/FY	Civil Service Project Management Staffing (Full Time Equivalent) per FY
IA		0.3	0.12
IV&V	Small	0 – 4	0.2
	Medium	5 – 10	0.4
	Large	11 – 20	0.6
	Special	21 and up	0.8

Once the above resource estimation is performed, the results are provided to the customer projects. This provides an opportunity for any differences between the project and the IV&V Facility (e.g., mission risks, IV&V costs, and budget constraints) to be resolved; and enables the projects to factor the IV&V/IA costs into their budget planning. Budget estimates are also sorted by Enterprise and Center and provided to those organizations to support budget planning and to assist in monitoring compliance with the IV&V policy.

There are significant uncertainty factors in the above estimates. Actual project costs may vary from these estimates after software risk analyses are performed. However, for the purpose of estimating total IV&V Facility resources, individual project errors should tend to offset in the summation process. The resulting budget estimate provides a basis for the Facility to plan civil service staffing requirements, contracts, and other resources needed to support the NASA mission model. The Facility will continue to refine this budget estimation process as the database of projects receiving IV&V/IA increases.

Subsequent to the development of IV&V Facility resources plans, the staff of the Facility will work with project managers to refine IV&V plans and cost estimates based on a risk analyses, and will adjust the Facility plans accordingly.

6.2 IV&V Workforce

6.2.1 Workforce Functions

In coming up with the overall staffing resources needed to support the IV&V work forecast over the next 5 years, resources were categorized into five general areas:

- IV&V/IA
- Research/Office of Safety and Mission Assurance (OSMA)
- Software Engineering
- Facility Operations and Maintenance (O&M)
- Civil servant management and administration

Resource requirements were estimated for each of these areas as follows:

- IV&V/IA. As stated in Section 6.1, a number of assumptions are made in determining how to assess the civil servant and contractor staffing resources required to support the IV&V and IA efforts projected in the Mission Model.
- Research/OSMA. A basic assumption was made that the resources required to support research and OSMA will be restored to appropriate levels, correcting recent shortfalls.
- Software Engineering. Civil service staff will perform overall management of efforts to leverage IV&V capabilities to improve NASA's software engineering capabilities as described in

Section 8. Staffing priorities and/or proposed staffing levels will be adjusted if necessary as these activities evolve.

- Facility O&M. Substantial increases are not expected among the O&M staff supporting the Facility. Only nominal changes are anticipated.
- Civil service management and administration functions are also not expected to change significantly. Only a nominal increase is planned.

IV&V Facility resources planning will show current and projected staffing levels for civil service and contractors, identified by location (i.e., Facility vs development site).

6.2.2 Workforce Development

Realizing that attracting and retaining highly skilled and motivated people will likely be a key factor in ensuring the success of NASA's IV&V Program, several employee Focus Groups were conducted to discuss the specific challenges the staffing requirements pose. Two separate Focus Groups were conducted, one to address hiring, retention and recruitment, and the other to address training. Participation was voluntary and open to any Facility employee. A cross section of civil servant and contractor, technical and service oriented, and management and non-management people were included in each group. Additionally, the sessions were facilitated by The Center for Entrepreneurial Studies and Development, Inc. (CESD), which also provided consultation and assessment support. In anticipation of the focus group discussions, a survey was distributed to all Facility employees, requesting their views on a number of issues related to hiring, retention, recruiting and training. CESD compiled the results and provided them to each Focus Group. These results were used as a starting point in discussions.

Focus Group 1: Hiring, Retention and Recruitment

This group looked at the factors that affect attracting and retaining the right people at the Facility, including:

- Advantages/disadvantages of working at the Facility
- Current hiring and recruiting practices
- Key factors leading to attrition

A representative from the GSFC Human Resources Operations Office participated in this discussion in addition to Facility employees. It became clear that while each organization represented in the discussions had their own policies and guidelines to deal with, they each faced similar challenges in attracting and retaining qualified personnel. It was acknowledged that many of the suggested improvements and actions could be done on a Facility basis with collaboration from all organizations, thereby benefiting everyone. CESD prepared a summary of key findings and discussion points as well as a weighted list of improvement ideas for each of the three topics addressed (hiring, retention, recruitment). These results were distributed to each Focus Group participant. It was noted during these discussions that the challenges faced by the Facility are no different than those faced by other organizations in the local community. It was also noted that local, collaborative groups have been established to address these challenges and it was agreed that the Facility should actively participate in those groups. As a first step, the Facility will request participation in the West Virginia High Tech Consortium committee that is looking at these issues.

Focus Group 2: Training

This group looked broadly at training in several areas, including:

- Technical, skill-based training
- Degree-related training
- Professional development training
- Management/personal development training
- General Facility orientation

Academic representatives from West Virginia University (WVU) and Fairmont State College (FSC) and a representative from the GSFC Human Resources Employee Development Office participated in this discussion, in addition to Facility employees. To begin with, two basic questions were asked to assess how well the training and development needs of Facility employees are currently being addressed:

- How effective is the training and development process/planning?
- How well does content match advancing the mission of IV&V?

Using a scale of 1 to 10 (1 = not effective at all, 10 = highly effective), an average score of 3.0 and 2.9, respectively, was achieved for the two questions by the focus group participants, clearly showing that much attention is needed in this area. In the ensuing discussion, key factors affecting training were identified and a list of critical training courses needed was compiled. As in Focus Group 1, it became clear that many of the issues being highlighted were shared by most of the organizations in the Facility and many of the actions being suggested could benefit all employees. The discussion, which was focused on training that could be provided to all Facility employees, covered a wide range of desired topics as well as a number of possible methods for providing the training, including:

- On-site academic training through WVU or FSC
- SOLAR web-site training in such areas as Information Technology Security, Safety, Safety and Mission Assurance, etc.
- On-Site training on a variety of subjects brought from a number of sources
- Computer-based training like that currently available at the GSFC Learning Center at Greenbelt MD
- Mentoring and On-Job-Training (OJT) by senior members of the current Facility staff

CESD prepared a summary of key findings and discussion points along with a weighted list of improvement ideas for the Training Focus Group. These results were distributed to each focus group participant. It should be noted that while these discussions focused primarily on addressing the training requirements of the employees at the Facility, it was agreed that ultimately it would be desirable to provide training opportunities which are open to the local community as well. This will be addressed in future focus group discussions.

Each of these focus groups will meet again in mid-September to continue their discussions and refine their list of actions. A determination will be made as to whether further general discussions are necessary before a final action list can be prepared. At that point, a detailed, prioritized action list will be generated and submitted to the Facility Director and actionees will be assigned to the top three actions on each list. It will be their responsibility to assemble a team and prepare an action plan to address the assigned action, which will be provided to the Facility Director for approval. Periodic progress reports will be provided at the weekly IV&V Staff Meeting, which is attended by representatives from all of the organizations at the Facility.

Ensuring that sufficient numbers of civil servants and contractors are available who possess the requisite skills required to accomplish the activities discussed in this Program Plan is a key challenge. It is expected that the actions discussed above will help Facility management, both civil servant and contractor, deal with that challenge.

6.2.3 Workforce Model

IV&V Facility resources planning will identify the civil service and contractor staffing profiles needed to support the full IV&V requirements of NASA missions. Key staffing actions to meet significant workload changes will also be identified.

The number of IV&V PM required for the forecast workload is determined using a model based on the size of the IV&V project (Table 6.1-1). Four size categories are used (small, medium, large and special) and loading factors (.2, .4, .6 and .8) are applied to each, resulting in a percentage of an FTE needed to support each project. An additional loading factor of .2 for "other duties as assigned" is also applied to every potential FTE. The result is that most IV&V PMs support more than one project, with the exception of special IV&V projects, which have a dedicated Project Manager assigned full time.

It is expected that the contractor staffing will be provided through several contract vehicles, including the current Facility IV&V Omnibus contract and Indefinite

Delivery-Indefinite Quantity (IDIQs) through the General Services Administration (GSA). It is anticipated that the Omnibus contractor will utilize sub-contractors both locally and remotely to satisfy IV&V support requirements. Additionally, the Facility has already pre-qualified six contractors under GSA.

6.3 Facilities

The Facility was built in 1993, and includes a total of 55,000 square feet of space, with 35,400 square feet on the first floor and 19,600 square feet on the second floor.

The first floor space is broken down as follows:

- 15,800 square feet for the mechanical area (generators, chillers, batteries, boilers, loading dock, switchgear, etc.)
- 19,600 square feet of raised floor area
- 13,100 square feet (NISN Gateway, Educator's Resource Center (ERC), Omnibus Library, NASA Technical Library, entrance foyer, network servers, operations space, storage, and 16 office cubicles)
- 6,500 square feet not currently being used

The second floor space is broken down as follows:

- 130 offices and/or cubicles
- Conference rooms
- Break area
- Electrical/phone closets

Given the current utilization of facility office space, a third Focus Group was scheduled to address Facility space requirements.

6.3.1 Facility Focus Group

Focus Group 3 (Facility) discussed options for satisfying the space requirements for the Facility for both the near term and long term. Two representatives from the GSFC Facilities Management Division joined Facility employees for the discussion, which addressed several key facility factors including:

- NASA's Cooperative Agreement with WVU, the owner of the building
- Availability of office space in the local area
- Potential customers for the unused raised floor space on the first floor
- Potential expansion of the existing building

A list of issues were identified, as well as a list of ideas on how to address the expected shortfalls. While it was recognized that most solutions to the facility space issue would require considerable planning, coordination and time to execute, it was clear that both a short-term and a long-term plan would be needed. CESD prepared a summary of key discussion points, which were distributed to each focus group participant.

6.3.2 Facility Plan

The short term plan to address near-term increases in Facility staffing is to house additional civil servants within the building, with individual contractors responsible for finding space off-site for any additional employees. Additionally, WVU will investigate the availability of additional office space in the local area. Also, discussions will continue with the two potential customers for the unused raised floor space on the first floor. As a contingency, one or more of the conference rooms could be reconfigured to temporarily house employees while alternative arrangements are made. The unused raised floor space could also be used in this manner if necessary. However, it was strongly felt that neither of these options is suitable as a long-term solution. Therefore, they would only be used for a limited time, and only as a last resort.

The long-term plan is to establish a committee, led by NASA and WVU, that will do a complete analysis of the situation, validate the requirements and explore options. They will perform a cost-benefit analysis for each option, and provide the cost, proposed contract vehicle, and time period required for each. They will provide a proposal, with options, to the Facility Director by the end of CY2001. The proposal will be reviewed by NASA and WVU management for final agreement/approval, with implementation of the long-term facility plan expected to begin by the end of the first quarter of CY2002.

7 IV&V RESEARCH PLAN

7.1 Background

The goal of the Facility Research Program is to support NASA's development of safe and reliable mission critical software and to reduce risk for other software systems requiring high reliability or involving a major investment. This must be achieved while reducing software costs and maintaining schedule. The Facility Research Program uses a two-pronged approach to meeting this objective:

- First, much of the Facility research supports Software IV&V which is proven to result in safer and more reliable software. As the methods and techniques of software development are rapidly evolving, the Facility must constantly develop new tools and processes to effectively test this software. Without an on-going research program the Facility would not be able to address new development concepts such as intelligent systems or auto-generated code.
- An additional approach is through the development of software engineering tools, techniques, methods, and best practices. Software development organizations can use Facility research products to improve their software engineering practices. The use of these tools and the improvement of development practices increases the ease of IV&V implementation, but also decreases the risk and the necessity for IV&V.

The research role of the Facility is two-fold:

1. management of the Software Assurance Research program funded by the NASA Code Q/OSMA; and
2. research conducted by personnel at the Facility.

Under the OSMA Software Assurance Research program, research funds are provided to centers, universities, and industry through the Center Initiative (CI) Program as described in Section 7.2. Additional funds are set aside in advance to fund research at WVU as part of the Cooperative Agreement through the process described in Section 7.3.

In addition to managing the OSMA research effort, Facility personnel also conduct research. The Facility competes with Centers for OSMA funding, they acquire funding from other sources, and some research is funded internally. All research is conducted by government civil service employees or interns.

7.2 Center Initiatives

In structuring the CI research for the future, aspects that must be addressed are:

1. dissemination of call for proposals;
2. topics of research; and
3. proposal selection

7.2.1 Dissemination of Call for Proposals

NASA has an annual procedure for the call for research proposals that is issued as part of the NASA Level 1 Technical Program Plan. This Plan will identify research proposal topics and areas, and describe submission procedures. The Facility has been tasked with drafting the Level I Technical Program Plan for the Software Assurance Research Program by the Deputy Associate Administrator for Safety and Mission Assurance. The proposals are called Center Software Initiative Proposals (CSIP); awarded proposals are termed CIs.

In the past, although sent to all Centers, information on the software assurance Level 1 was primarily disseminated through the members of the NASA SWG. This narrow dissemination limited the research topics and potential Principal Investigators. In future years there will be a wider dissemination of the Level 1 call for proposals. In addition to normal distribution, it will be sent to the CIO, the Systems Management Office (SMO), and the System Mission Assurance Office (SMA) at each Center. The objective is to widen the pool of applicants, with the expectation that this will also the increase the areas of proposal topics. A formalized dissemination process of the Level 1 Program Operating Plan (POP) call is under development to include members of the SWG, CIO, SMO, and SMA.

7.2.2 Topics of Research

Prior to the FY01 call, specific topics of desired research were suggested, although research could be proposed in any area relating to software assurance. This resulted in the list of topics changing yearly based on the current "hot topics." Continuity of proposals that spanned more than one year was lost. Projects or Centers that could not relate to these "suggested" topics did not submit and in some cases lost interest in the research program.

For FY01, a revised Level 1 call was issued eliminating a list of topics. Instead, the relationship to IV&V was indicated as a primary driver to topic selection. IV&V relates to a broad base of software assurance topics, and proposals were to relate to some aspect of IV&V. This allowed proposers free reign in research topic selection as IV&V relates to activities within their Center. It is anticipated that this approach will be continued, encouraging research focused on the software assurance needs and software development environments at each Center.

7.2.3 Proposal Selection Process

In the past, different selection methods were used, including committee selection by the SWG, selection by the Director of the Facility, selection by Facility employees, and combination of all of these techniques. As part of the Facility transition activities, a new selection approach was used this year. This approach will be continued if successful. The objectives of this approach are to:

1. make all submitters aware of what would be important in the selection of the proposals;
2. make the selection impartial;
3. decrease time needed for selection; and
4. have multiple sources of evaluations for each proposal, including each Center, University and industry evaluation.

7.2.3.1 Evaluation Criteria

The revised Level 1 plan specified the criteria (shown below) that would be used to evaluate each proposal. Additional information on the criteria was placed on the Facility website.

- Potential contribution to mission success
- Potential contribution to mission assurance
- Potential contribution to more efficient software development and lifecycle management without degrading quality safety and reliability.
- Relevance to existing or planned NASA programs and projects.
- Potential for technology transfer to other NASA or industry programs and projects.
- Uniqueness of the research.
- Clarity of objectives, methodology, and success criteria
- Competency/experience of the researcher

7.2.3.2 Evaluators

As the research sponsor, the Deputy Associate Administrator for OSMA designates the Chair of the Selection Committee. The Facility will be represented on the Selection Committee by the staff member responsible for CSIP and CI activities. The Chair and the Facility representative serve as reviewers and final arbiters in the proposal selection.

In the Level 1 plan, the Facility is delegated the responsibility to assist in the selection of the proposals. All proposals are submitted to the Facility. The Facility is assisted in proposal coordination by their contractor. In order to improve impartial selection, the contractor then removes all identifying material in headers and within the body of the submission, such as Principal Investigator and Submitting Center.

To ensure centerwide representation in proposal evaluation, members of the SWG will be asked to evaluate the proposals. The SWG represents the highest level of expertise in software development within NASA, and each center has representation within the SWG. Each Center will submit evaluations, and Centers may evaluate their own proposals. Since there are usually over 40 proposals, this task is most efficiently done if proposals are divided among multiple reviewers.

Professors at WVU serve as an excellent source of reviewers for proposals; representing the academic viewpoint. Professors are also generally knowledgeable in what is expected in a research proposal and have experience in doing research. Knowledge gained from the review process helps identify potential research projects for WVU, possibly of a more theoretical nature.

Reviewers from industry are harder to identify. One source is to identify experts in the areas which proposals are received, and request their assistance. For FY01, the contractor provided two industry experts to conduct independent reviews. Through this task, each proposal was reviewed by two experts in the proposal topic area. This aspect of review will be further investigated prior to next years submissions.

Based on successful proposal selection for FY01, it is anticipated this selection of evaluators will continue in future research selection.

7.2.3.3 Evaluation process

An automated web based evaluation process is the most effective. For FY01, a web site was developed where each reviewer entered a score of 1-5 for each criteria for each proposal. These scores were automatically tallied as received, and in the final review, reports were issued as needed. This web site and reports will be used in future evaluations.

7.2.3.4 Final Proposal Selection

Based on the scores from all three evaluation groups and opinions of the Chair and Facility representative, proposals are then selected. The amount of money available for disbursement determines the amount and number of proposals selected. A portion of CI funding is reserved for research to be done by WVU.

In the CI selection, preference should be given to those proposals that are continuing from previous years. If these are not continued, money should be reserved to close out these initiatives in an orderly fashion such that work benefits are not lost. It is recommended that all Centers receive research funding, although primary award selection should be made on the merit of the proposals. Selected proposals should be notified by the Facility in a timely fashion.

7.3 West Virginia University Research

A portion of the CI funding is used to fund research at WVU. In the past, this research was in the form of full-time researchers, part time research assistants, and interns. However, by July 2000, all full-time researchers assigned to the Facility had left the University, resulting in little formal structured research activity by WVU at or for the Facility.

It is planned that future funding of research at WVU will be conducted in a similar fashion as the CIs but with a lesser degree of review. A call for proposals should be issued, similar to the Level 1, containing the evaluation criteria. Proposals should be solicited from all departments within the University. It is anticipated that the proposals will be primarily theoretical, but may also be applied. All proposals should address some aspect of IV&V and show potential benefit to NASA, with deliverables specified. Requested conference attendance and presentation should be included in the proposals. The call for university proposals should be issued once the CIs have been selected with the intent that WVU research complement the CIs.

Proposals should be sent to the Facility after review and endorsement by the University.

Selection of the proposals should be done by the Chair of the CSIP selection and the Facility representative. Preference should be given to multi-discipline proposals and those including use of students. Conference attendance should be evaluated based on the value added to NASA of the conference presentation and cost of attendance. It is not recommended that full time researchers be assigned to the Facility, but rather a broader research approach be applied.

This approach has been successfully used for FY01 research funding and will be continued.

7.4 Research Monitoring

Once the period of performance has begun, the Facility, through the Level 1, is delegated the responsibility to conduct bimonthly program management reviews (PMRs) with each principal researcher. The monitoring of the CIs is done by an Facility civil service staff member with contractor support. The Facility with hold a quarterly PMR by teleconference or video conferencing.

7.5 Anticipated Future Center Initiative Research Funding

The IV&V Facility will develop plans for multi-year research funding and submit budget requests through the NASA POP process.

7.6 Strengthening Research Opportunities

As part of the GSFC administrative operations, the Facility will be included in the notification of all POP Calls for research funding from NASA, GSFC, industry, and other areas. For example, each year there is a call for funding from the Director's Discretionary Fund (DDF) for employees within GSFC. With the Facility now being part of GSFC, the Facility staff will now be included in that call.

The GSFC CIO is working to develop a process to strengthen IT proposal submissions. This process includes a review of proposals prior to submission to determine areas of weakness. If proposals are similar, their combination to form a stronger proposal is investigated. For example, a group of proposals currently submitted on the first step of a two step proposal call from Ames Research Center will be reviewed by the GSFC CIO and a supporting group in early September to determine where they can be strengthened. This review will include the two proposals by the Facility. An example of the success of this process is in a recent research funding call by the NASA CIO. Three of the four proposals awarded funding were from GSFC.

7.6.1 Research Proposal Planning

In order to effectively prepare for writing research proposals, it is important to know in advance when calls are approximately expected and what are the expected topics. This allows for advance preparation, expecially if an idea is conceived and identification of funding is an issue. Knowing there will be a specific research funding call and how this idea fits the topic areas assists in planning.

In conjunction with this need, the Facility will maintain a database of proposal calls from NASA, GSFC and Industry with sufficient information to allow readers to determine, based on this historical data, if a relevant proposal call is anticipated. This will be maintained on the Facility homepage.

7.6.2 Conference Directory

Each year there are many conferences sponsored by industry, academia, and professional societies. Each conference, workshop, and symposium has unique aspects that are not apparent by reading the program or call for submission. Knowing about these conferences and their characteristics is important to submitters so submissions can focus on conferences with a higher probability of acceptance.[2] Also knowing a conference is generally attended by 50 people or 500 people can help determine the value of the conference (does the base of information dissemination justify the cost?). This information can also be valuable in planning budgets for the upcoming year.

In conjunction with the research aspects, the Facility is identifying the requirements for a database on conference information. Questions being explored include definition of the database contents, data base content management responsibility, etc. Since some of the data

[2] For example, the *IEEE Software Metrics Symposium* is very technical and does not have many industry papers or applications. Knowing this, an author might chose to submit the case study to a more industry-focused conference such as *Applications in Software Measurement*. Another valuable but little known conference is the *Software Technology Conference* sponsored by the military but attended by about 4,000 people, and about 50% military, 75% (military and civilian) government.

might be sensitive (e.g., previous attendees, assessment of the value of the conference), how the data is disseminated must be carefully determined.

8 OPPORTUNITIES FOR LEVERAGING IV&V CAPABILITIES

The stated objective of the Business Plan was to identify steps needed to fully utilize IV&V to minimize risk in NASA programs, building on and extending the capabilities of NASA's Facility. Two potential activities were described that would strengthen software development throughout NASA and support potential expansion of the business base of the Facility, while leveraging the current capabilities. These included:

1. the development of a Software Engineering and Assurance Consortium and
2. the development of a central repository of information on software development tools that would support IV&V and related software engineering activities.

The Business Plan also identified the potential for collaborating on IV&V-related work with other Government entities where mutual benefit could result. This included but was not limited to Agencies that have a local West Virginia presence, such as the State of West Virginia, the Federal Bureau of Investigations, and the Coast Guard, as well as Agencies remote from West Virginia. This is further discussed in Section 8.3.2.

The following sections address the feasibility and potential implementation of these initiatives. These opportunities will be pursued to the extent possible without interfering with the primary objective of providing effective IV&V support to a much larger customer base.

8.1 Software Engineering and Assurance Consortium

8.1.1 Background

IV&V activities span the entire life cycle of software development, from requirements to release. The industry of software development is very fast paced. In order to stay on the cutting edge of science and space exploration, NASA must continually identify new approaches, new ideas, new techniques, then write the software to achieve or implement them. To perform IV&V comprehensively and effectively on these cutting edge projects requires tapping the depth and breath of knowledge beyond NASA's resources. It also is not cost effective to develop all techniques, methods and tools just for NASA when other industries have already spent resources to develop and refine many of the needed items. NASA has much to contribute to the world of software development, but it also has much to learn to effectively perform IV&V in a fast paced software development world.

It naturally follows therefore, that a partnering arrangement with other organizations in industry and academia to share knowledge and information in software engineering would benefit not only NASA software development organizations and projects, but that other organizations could learn from NASA as well. A framework for sharing information would benefit all participants.

A Consortium is defined as "*an arrangement, combination or group (as of companies) formed to undertake an enterprise beyond the resources of any one member*."[3] A Consortium was proposed in the IV&V Business Plan, to be supported by the Facility, to "assist in deploying state of the art software engineering and assurance technology throughout NASA." After further consideration, a consortium broader in scope than originally outlined in the Business Plan was determined to provide more benefit. A Software Engineering and Assessment Consortium (SEAC) is envisioned that would provide a gateway for technology to produce substantial, measurable improvement in software project performance, as demonstrated by metrics for product reliability, product safety, cost/schedule performance and estimation accuracy.

[3] Webster's Ninth New Collegiate Dictionary, 1990

8.1.2 Proposal

The objectives of the NASA SEAC are to:

1. Support the SWG in forming a NASA-wide software engineering and assessment community that can exchange ideas, coordinate work, and collaborate to meet Agency goals and plans;
2. Support Agency software process improvement and product assurance initiatives;
3. Provide a source of information on software engineering and assessment; and
4. Identify and support industry and academic sources of software development expertise.

After extensive discussions with members of NASA software community, IV&V community, and NASA's SWG, it was determined that this Consortium would best serve NASA if it encompassed organizations from within NASA, other government agencies, and industry. The NASA part of the Consortium is formed by software engineering and assurance organizations working through the SWG. NASA Centers, such as GSFC and the Jet Propulsion Laboratory (JPL), have organizations that have international recognition for their work in software development and software assurance, but often these organizations, such as the Software Engineering Laboratory at GSFC and the Software Process Assurance Resource Center at JPL, have little recognition throughout the Agency for their work in process improvements and metrics, although they have received international awards for their work. The SWG is chartered by the Office NASA Chief Engineer and Engineering Management Council[4] and has two members appointed from each Center that are considered experts in areas of software development. However, their work may not known to all software development project managers. At every Center, there is a group, formal or ad hoc, that has an area of expertise that is needed by all software development managers, but is usually unknown. As part of the Consortium however, these members will retain their identity within their management structure.

However it is not cost effective for NASA to always create new or unique policies and methodologies for software development when organizations, companies and academia have already developed and tested techniques, now proven to be effective. As discussed, the software development world is changing too fast for one organization to develop all tools, techniques, etc. For example, the Software Engineering Institute (SEI) at Carnegie Mellon University in PA has developed tools and techniques to improve software development, specifically the Capability Maturity Model (CMM)/Capability Maturity Model Integration (CMMI). It is proposed industry organizations such as the SEI be invited to participate in the Consortium.

Academia also has made major contributions to NASA software development activities and within industry. For example, the Fraunhofer Center located at the University of Maryland, emphasizes software engineering, software development practices, and software processes using application development, feedback, and learning as the basis for improving software development technologies.

The SEAC management needs a home within the NASA-wide organization and should be supported by a SEAC Support Team (SST). It is anticipated the SEAC Support Team will be resident at the Facility in Fairmont WV, as this meets all organizational needs and has the support experience. The benefits of the Consortium crosses all Centers and benefits all software development activities, including IV&V. The SST would serve as an information conduit to customer organizations, conveying information about software engineering and assurance technology.

8.1.3 Implementation

8.1.3.1 Membership

Below is a list of potential members for the SEAC. Initially the SEAC is expected to be a small group with representative from each group – NASA, Industry and Academia. From the Center groups, those that were identified at the writing of this plan are listed. One of the objectives of this Consortium is to identify these groups, formal or ad hoc.

[4] The SWG charter is located at the following URL: http://www.ivv.nasa.gov./SWG/charter/index.shtml

8.1.3.2 Potential Members

NASA SWG
NASA Center Groups (not an exhaustive list)
- Software Engineering Process Groups (SEPG)–LaRC
- Software Engineering Laboratory (SEL) – GSFC
- Software Assurance Technology Center (SATC)–GSFC
- IV&V Facility–GSFC
- Usability Laboratory (ad hoc)–GSFC
- Software Process Assurance Resource Center (SPARC)–JPL
- Mission Support Process Team (MSP)–JPL
- Information Technology Center–ARC

Software Engineering Institute (SEI)
West Virginia High Tech Consortium (WVHTC)
West Virginia University (WVU)
Fairmont State College (FSC)
Fraunhofer Institute
University of Maryland (UM)

8.1.3.3 Organization

In the basic organizational structure, the SWG will coordinate the overall Consortium activities, supported by the SEAC Support Team at the Facility. Each member of the Consortium will retain their individual identity. The SEAC is an organization in which communications and collaboration is between peer organizations in support of the high quality software development. Roles and responsible will be defined by the SWG in cooperation with other members of the consortium. Once members have been identified and agree to participation, a Charter will be developed.

This activity will be managed by the OCE, supported by the NASA SWG. This business opportunity is still in the concept stage. Implementation details will be further developed after the SWG has completed its work on the development and application of the IV&V Policy and Criteria.

8.2 Software Tool Evaluation

8.2.1 Background

One of the current activities at the Facility is the management of tools – software that is used to enhance the IV&V activities or support software development. Many such tools exist, some become part of the delivered software, others are used only in the software development, but there is a myriad of such tools in use by projects for whom IV&V is done. For many of these tools, the licenses or seats are held by the Facility. In almost all cases, the tools were purchased by the projects.

One of the objectives of identifying potential Facility opportunities is to leverage off the current capabilities to expand its business base. Software development organizations throughout NASA are always faced with the challenge of selecting the appropriate tools to maximize the efficiency of the development process and produce high quality reliable code at minimum cost. Given the overwhelming number of tools on the market, choosing the right tool is a difficult decision and can be an expensive mistake. Currently, each project must identify tools for use based on ad hoc information available possibly from prior experience or recommendations. Unfortunately, this is not always the most effective method for choosing a tool.

Putting together these two points, that projects need information on tools for software development, and the Facility has experience with a large number of tools, the logical conclusion is for the Facility to create a repository of information and tools used by NASA projects for software development and IV&V. This was the proposal in the Business plan, and during the transition period, investigation has supported the feasibility of this type of repository. The results show that the Facility maintains valuable agency knowledge pertaining to the spectrum of software tools available. For each of these tools, a short synopsis of the usability was written by a WVU intern. This information is available to NASA project managers to assist them in determining if a tool is right for their project, but needs to be converted to a more usable format.

8.2.2 Proposal

This business growth proposal is a multifaceted approach. The first component is the establishment of a database of information on software development tools. Initially, the database would contain information on existing tools under the management of the Facility. Projects that are currently using the tool or have used it would be identified for reference information on tool usage, (e.g., ease of use – determining the accuracy of manufacturer's information). Using a web-based search engine, projects would be able to retrieve this information prior to purchasing any tools. Having this information has the potential for cost savings to projects.

The second aspect of this new business activity would be assisting software development projects in selecting the optimal tools for their application and environment from the database of existing tools. This is the primary focus of this business opportunity since most of the information for the first activity is available.

8.2.3 Application

The following steps would be carried out in establishing this role for the Facility:

1. Determine users and requirements
   During the transition activities, a comprehensive list of projects and contact personnel was developed. This list will serve as an excellent reference for a survey to determine what tools are currently in use and any needs of the projects for a specific type of tool or information on tools. Questions the project manager might ask about a tool being considered for use could also be investigated. NASA's SWG members would also serve as an excellent reference, using their knowledge to help identify requirements for this activity. Projects currently performing IV&V could also serve as references for requirements. Inquiries to the members of the Consortium (discussed in Section 8.1) would also serve as inputs for the requirements, or possibly provide data on tools.
2. Define the scope
   To ensure that this activity does not become all encompassing, the scope of tools to be included must be defined. Initially, the following tools application domains are recommended:
   - Requirements: Tools that deal with extracting, measuring, and/or performing analysis techniques on a project's requirements
   - Modeling and Simulation: Tools that mimic real world events or objects and produce scenarios or estimations in response to user or environmental inputs
   - Configuration Management: Tools that deal with managing elements that are being created and updated over the projects' lifetime
   - Risk Management: Tools that identify, measure, track, report, or maintain information relative to the risk's associated with a project
   - Interface Analysis: Tools that control the data acquisition from one object to another, and could also perform analysis to verify the data kept its integrity through the process.
   - Code Analysis: Tools that perform static or dynamic analysis on source code
   - Tracking and Tracing: Tools that track items in a project that are being transferred, replaced, or monitored
   - Test Management: Tools that deal with generating test cases or managing them
   - Design: Tools that deal with software architectures and/or designs for the purposes of development and analysis
   - Project Management: Tools that lend support and/or generate reports to project managers.
3. Development of the database and web search engine

It has been determined that the Facility has the server capabilities to host the database and search engine. The current information stored on tools will need to be reformatted for the database. Some potential technologies being explored include:

- Intelligent Agents: Maintains meaningful and current tool information in the repository
- Language theory and Graph theory: Optimal search and evaluation strategies based on languages developed to represent the semantics of the tools
- Intelligent Selection strategies: Improves on the proven techniques and algorithms such as scale-based, rank-based, and cost-based

This new business growth opportunity has been determined to be feasible and profitable to NASA. Further work will be performed to develop more detailed plans and to establish funding.

8.3 Potential Efforts with Other Government Agencies

The contributions of the Facility to the NASA mission are anticipated to be directly transferable to other agencies and departments within the Federal government. The reliance on software for mission success spans virtually all federal functions. There are three types of collaborations that could be pursued by the Facility:

- Utilization of the building's computer facility
- Performance of IV&V for other Government organizations
- Collaborative Information Exchange

8.3.1 Computer Facility Utilization

The Facility has a world-class raised-floor computer space located on the first floor of the building, with back-up power supplied by redundant diesel generators and a fuel tank with ample capacity. There are currently no opportunities to utilize the space to its best advantage for NASA systems. The Facility entered into an agreement in FY01 with another Federal organization for use of some of the available space. The Facility will continue to discuss agreements with other potential users that can utilize the computer facility effectively and take advantage of NASA's investment in the back-up power systems. Priority will be given to use by another government agency, preferably for an application where there is also an opportunity for collaboration in IV&V activities.

8.3.2 Performance of IV&V for other Government Organizations

As the Facility reaches the level of staffing needed to provide IV&V support to the expanded list of NASA missions, contacts will be initiated with other government organizations that are involved with major software development projects with high reliability requirements. The purpose is to identify areas where the expertise of the Facility can be of assistance. Of particular focus will be multi-billion dollar programs that are early in their development life cycle (e.g., the Department of Defense's National Missile Defense program; modernization programs within the U.S. Customs service, the Federal Aviation Administration, and the Internal Revenue Service). The performance of IV&V on programs of such size and national importance will contribute to the potential success of these programs, increase the national prominence of the Facility, and provide a larger base of long-term programs for the Facility to complement the International Space Station and Space Shuttle programs. Establishing a larger base of IV&V efforts at the Facility will provide stability during any fluctuations in NASA mission requirements, attract a larger and deeper skill base to the region that will also benefit NASA programs, and broaden the IV&V team's experience in applications, tools, and techniques.

8.3.3 Collaborative Information Exchange

Most of the software engineering and development challenges NASA faces are not unique to this Agency. Rather than attempt to solve all of the problems ourselves, the Facility will work synergistically with other government entities to leverage each other's strengths to combat these challenges (e.g., continuing investigation of V&V techniques for Commercial Off-The-Shelf (COTS) software with the FAA's Technical Center). The Facility will endeavor to enter into information exchange arrangements with various government organizations starting in FY01 and build upon this endeavor throughout the subsequent years. An added purpose of these collaborations is to enhance the prestige and recognition of the Facility in the software engineering community of other government agencies. This will assist in endeavors

to increase the future business base described in paragraph 8.3.2. This act may become part of the consortium as described in Section 8.1.

9 OPERATING PLAN UPDATE PROCESS

Estimated multi-year budget profiles for IV&V and other Facility work will be maintained in an IV&V Operating Plan, documented separately from this Program Plan to facilitate updates. The Facility will work with Enterprises and Program Offices to maintain a current model of NASA missions and the estimated costs to current and future projects to perform IV&V. This update process is illustrated in Figure 9-1.

The process defined in Section 5 of this Program Plan will be executed at least on an annual basis to update the projected IV&V Mission Model. The processes defined in Section 3.3.2 and Section 6.1 will be used to update estimates of IV&V costs for missions in the IV&V Mission Model. Information gained from risk assessments performed with individual projects will be used to refine the understanding of IV&V requirements and corresponding cost estimates. The Facility will communicate estimates to project, program, and Enterprise offices to provide information customer projects need to support their planning and budget submissions, and to resolve any misunderstandings. The allocation of M&O costs to each Enterprise for the coming year will be updated based on projected proportional use.

This update process will be performed annually in the December time frame to provide timely information to projects for the POP process.

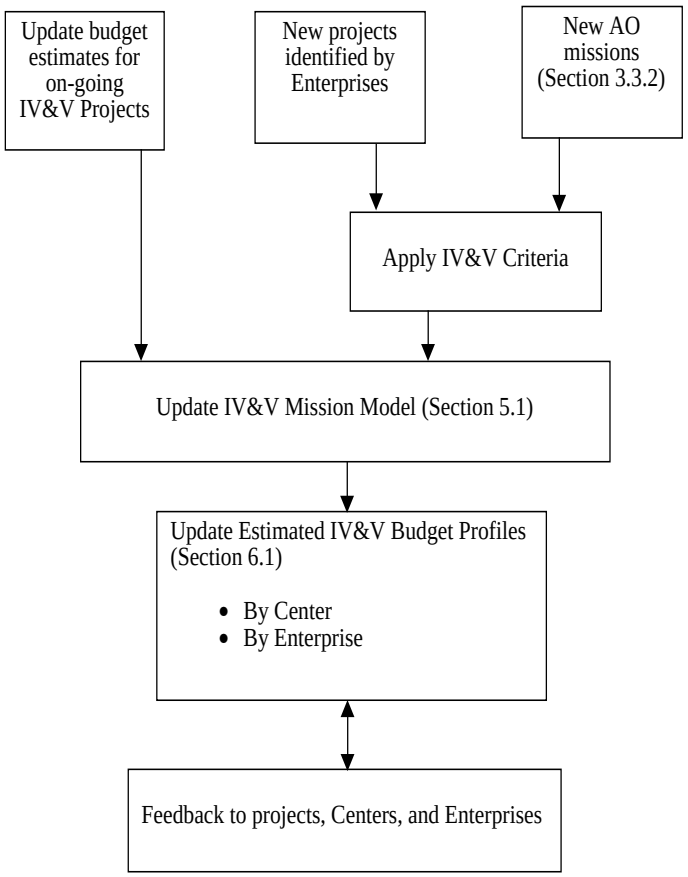

Figure 9-1 Operating Plan Update Process.

ACRONYM LIST

AO	Announcement of Opportunity
CESD	The Center for Entrepreneurial Studies and Development, Inc.
CI	Center Initiative
CIO	Chief Information Officer
CMM	Capability Maturity Model
CMMI	Capability Maturity Model Integration
COTS	Commercial-off-the-shelf
CSIP	Center Software Initiative Proposal
DDF	Director's Discretionary Fund
ERC	Educator's Resource Center
FSC	Fairmont State College
FTE	Full-Time Equivalent
GPMC	Governing Program Management Council
GSA	General Services Administration
GSFC	Goddard Space Flight Center
HQ	NASA Headquarters
IA	Independent Assessment
IDIQ	Indefinite Delivery–Indefinite Quantity
ISO	International Standards Organization
IT	Information Technology
IV&V	Independent Verification and Validation
IV&V PM	Independent Verification and Validation Project Manager
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center
LAN	Local Area Network
LaRC	Langley Research Center
MOA	Memorandum of Agreement
MSP	Mission Support Process Team
NASA	National Aeronautics and Space Administration
NISN	NASA Integrated Services Network
NPD	NASA Policy Directive
NPG	NASA Procedures and Guidelines
O&M	Operations and Maintenance
OCE	Office of Chief Engineer
OJT	On-Job-Training
OSMA	Office of Safety and Mission Assurance
PACT	Program Activity Commitment Term
PM	Project Manager
PMR	Program Management Reviews
POP	Program Operating Plan
SATC	Software Assurance Technology Center

SEAC	Software Engineering and Assessment Consortium
SEI	Software Engineering Institute
SEL	Software Engineering Laboratory
SEPG	Software Engineering Process Groups
SMA	System Mission Assurance Office
SMO	Systems Management Office
SPARC	Software Process Assurance Resource Center
SST	SEAC Support Team
SWG	Software Working Group
UM	University of Maryland
V&V	Verification and Validation
WVHTC	West Virginia High Technology Consortium
WVU	West Virginia University